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Reducing Plastic Marine Debris through Policy: A Comparison of Melbourne and San Francisco

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Introduction

Between 1958 and 1973, the United Nations Convention on the Law of the Sea met a number of times to determine the boundaries for countries' control over their surrounding oceans. U.S. President Harry Truman had previously claimed 200 nautical miles off the coast of all U.S. states and territories in 1945, and other countries followed suit. The United Nations' Convention on the Law of the Sea completed a treaty in 1982 to standardize countries' control of the ocean off their shores to be 200 nautical miles of exclusive economic rights to the ocean off the coast of countries, and 12 nautical miles of territorial sea.[1] This treaty gave both the United States and Australia the economic rights to a greater area of ocean than they each have of land. With these rights, the countries have the responsibility to keep their areas of the ocean clean in order to maintain the prosperity and biodiversity that make the ocean unique.[2]

One issue that both the United States and Australia have begun to address in recent years through public policy is the debris entering the ocean through both ocean and land-based sources. Marine debris is defined by the National Oceanic and Atmospheric Administration as "any persistent solid material that is manufactured or processed and directly or indirectly,

[1] "United Nations Convention on the Law of the Sea of 10 December 1982," Oceans of the Law and Sea United Nations, last modified August 22, 2013, http://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm
[2] Intergovernmental Oceanographic Commission, *National Ocean Policy. The Basic Texts from: Australia, Brazil, Canada, China, Colombia, Japan, Norway, Portugal, Russian Federation, United States of America* (Paris: UNESCO, 2007), 8-10, 247.

intentionally or unintentionally, disposed of or abandoned into the marine environment."[3] The presence of marine debris is concerning because of the harmful effect it can have on both wildlife and human health. Approximately 6.4 tons of debris is estimated to enter the ocean every year from a combination of land-based and ocean-based sources, although some scientists believe this estimation is low.[4] Debris originating from land can come from individuals littering, improper management of construction facilities, overflowing storm water systems, and from natural events such as hurricanes or floods. Debris from ocean based sources can come from merchant ships and cruise liners if they are improperly managed, fishing vessels, oil and gas platforms, or from accidental losses due to strong seas.[5] Marine debris can include glass, paper, and metals, but the most common and harmful debris in recent years are synthetic materials such as plastic.[6]

In the past six decades, the international increase in the use of plastic has dramatically changed the composition of debris in the ocean. Plastic has become an appealing option for manufacturers because of its strength, durability, light weight, and inexpensive cost. The same characteristics that have made plastics popular among manufactures have made plastic debris a serious hazard to marine environments. Due to its light weight, plastic particles typically float and can be easily transported by ocean currents.[7] Some of the debris will be washed back to

[3] "What is marine debris?" NOAA, accessed February 22, 2014, http://oceanservice.noaa.gov/facts/marinedebris.html
[4] A. McIlgorm, H.F. Campbell, and M.J. Rule, *Understanding the Economic Benefits and Costs of Controlling Marine Debris in the APEC Region* (New South Wales: National Marine Science Centre, 2008), 2.
[5] "Marine Debris Sources," United States Environmental Protection Agency, accessed April 25, 2015, http://water.epa.gov/type/oceb/marinedebris/md_sources.cfm
[6] Murray R. Gregory, "Environmental implications of plastic debris in marine settings – entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions," *Philosophical Transactions of the Royal Society* 364 (2009): 2013-2014.
[7] Jose G.B. Derraik, "The pollution of the marine environment by plastic debris: a review," *Marine Pollution Bulletin* 44 (2002): 842-852.

shore, through the tides, while other debris is carried out to sea. This allows for the collection of plastic particles in remote locations, where it can take hundreds of years to break down.[8] Some of the debris remains in the ocean in areas of high concentration, caused by the circular current of ocean gyres. While the ocean currents are constantly moving, the center of the gyre is often calm and stable, allowing for the marine debris to become trapped. Because many of the materials trapped in the gyres are not biodegradable, large amounts of debris can accumulate, such as in the Great Pacific Garbage Patch in the North Pacific Ocean.[9] Additionally, there have been several documented cases of invasive species being brought into new marine environments by lodging onto plastic particles, which has the potential to have detrimental effects on local species.[10] Plastic debris currently accounts for 60 – 80 percent of the total marine debris in the oceans, making it the single largest contributor to the problem of ocean debris.[11]

Presently, plastics are estimated to negatively affect 663 species, including seabirds, mammals, and turtles. Plastic debris accounts for over 80 percent of the total marine debris impact associated with these species.[12] Common ways in which plastic debris harms species include ingestion, entanglement, and smothering.[13] With the increasing media coverage of the harms caused to marine life from plastic pollution, public support has risen for legislation aimed at reducing human waste in the ocean. Studies indicate that 60 - 80 percent of the marine debris results from land-based sources. This debris can enter the ocean from direct littering on beaches

[8] Gregory, "Environmental implications of plastic debris," 2013-2020.
[9] "The Great Pacific Garbage Patch," National Geographic, accessed April 25, 2014, http://education.nationalgeographic.com/education/encyclopedia/great-pacific-garbage-patch/?ar_a=1
[10] Derraik, "The pollution of the marine environment," 842-852.
[11] Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel, *Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions,* (Montreal: Technical Series No. 67, 2006): 8-10.
[12] Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel, *Impacts of Marine Debris on Biodiversity,* 10-12.
[13] Gregory, "Environmental implications of plastic debris," 2014-2018.

and piers, or indirectly from litter washed into storm drains. Legislation regarding land-based sources of debris has the potential to be very effective in reducing levels of plastic pollution in the oceans because of the large amount of debris coming from these sources.[14]

This study aimed to compare the composition of debris found on beaches in Melbourne and San Francisco in order to analyze the levels of plastic pollution. The data found will allow for an analysis of the quality of each of the cities' beaches as well as the effectiveness of public policy aimed toward reducing the levels of debris stemming from these regions. These cities were chosen for their large size, with approximately 4 million residing in Melbourne[15] and 7 million in the San Francisco Bay Area.[16] These populations are augmented by the number of tourists traveling to each city every year. In 2012, Melbourne had 1.7 million tourists, while San Francisco had 16.5 million visitors.[17] The large number of tourists in each city contributes to the number of visitors to San Francisco and Melbourne's beaches, despite the fact that these beaches are not a top tourist attraction for either city. Both cities have a moderate climate that encourages a thriving tourist economy to participate in recreational beach activities. A final similarity between Melbourne and San Francisco is that they both surround a bay, with Melbourne located on Port Phillip Bay and San Francisco located on the San Francisco Bay. This study collected data on the marine debris, especially plastic debris, found on various beaches surrounding the cities. Additionally, this study aimed to analyze the current government efforts to reduce marine

[14] "The Problem with Marine Debris." California Coastal Commission, accessed February 22, 2014. http://www.coastal.ca.gov/publiced/marinedebris.html
[15] "2011 Census Quick Stats." Australian Bureau of Statistics, last modified March 38, 2013. http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/2GMEL
[16] "Selected Census from the San Francisco Bay Area." Bay Area Census, accessed March 8, 2014. http://www.bayareacensus.ca.gov/
[17] "San Francisco Visitor Industry Statistics." San Francisco Travel, accessed March 8, 2014. http://www.sanfrancisco.travel/research/

debris stemming from the beaches, as well as make policy recommendations for continuing the efforts to reduce marine debris.

Methods

In this study, multiple beaches were surveyed and examined throughout the greater San Francisco and Port Phillip Bay regions. In the San Francisco Bay Area, the study included thirteen beaches over a year and a half period. In total, the San Francisco Bay Area comprises nine counties, shown in Figure 1,[18] six of which were studied. The first group of beaches is located in Point Reyes in Marin County, a national seashore approximately 30 miles from San Francisco. These beaches have often been named some of the cleanest beaches in California,[19] and include Drakes Beach, Kehoe Beach, Limantour Beach, and Palomarin Beach. Another group, part of San Francisco's Golden Gate National Park Conservancy, includes Baker Beach, Rodeo Beach, Stinson Beach, and Crissy Field Beach.[20] This study also included Ferry Point Beach in Contra Costa County, Crab Cove Beach in Alameda County, Linda Mar Beach in San Mateo County, South Beach in San Francisco County, and Coast Camp Beach in Sonoma Country.

Figure 1: Map of San Francisco Bay Counties

[18] "One Bay Area." Association of Bay Area Governments, accessed March 9, 2014. http://scs.abag.ca.gov/about.htm
[19] "Beaches of Point Reyes." National Park Service, last modified March 31, 2014. http://www.nps.gov/pore/planyourvisit/beaches.htm
[20] "Rodeo Beach." Golden Gate National Parks Conservancy, accessed March 29, 2014. http://www.parksconservancy.org/visit/park-sites/rodeo-beach.html

In the Australian state of Victoria, several beaches were surveyed through the Australian Marine Debris Initiative around Port Phillip Bay. Surveyed beaches included Chelsea Beach, Western Port Bay, and St. Kilda Beach located in Melbourne. South of Melbourne, Caraar Creek Beach in Mornington and Lighthouse Beach in Queenscliff were surveyed. East of Melbourne, several beaches were surveyed along the Great Ocean Road, a popular Melbourne tourist attraction, including various locations along Five Creeks Fairhaven Beach, Painkalac Estuary, and Torquay Surf Beach. Finally, data were collected at Cotters Beach and Squeaky Beach in Wilsons Promontory National Park, a popular site for camping and hiking in Victoria.[21]

In acquiring data on marine debris, two main sources were used throughout the study. The first source was data collected directly while working with the Turtle Island Restoration Network, using the National Oceanic and Atmospheric Administration (NOAA) protocol for surveying and monitoring marine debris on beaches through a standing-stock study. This protocol surveys a 100 meter section of shoreline divided into five meter sections, known as transects. A sample survey can be seen in Figure 2, which shows the GPS tracking from a beach survey at Crab Cove in Alameda County. Before arriving at the beach, four of the twenty transects are selected to be surveyed. For each transect, the width of the beach from the water's edge to the end of the shore is measured. In order to maximize the amount of debris found, all beach surveys for this study were conducted at low tide. All items found on the beach are recorded for each transect, categorized by material and

Figure 2: Crab Cove Beach Survey

[21] "Wilsons Promontory National Park." Parks Victoria, accessed February 21. 2014. http://parkweb.vic.gov.au/explore/parks/wilsons-promontory-national-park

size. Various characteristics of the beach, such as its accessibility to the public or proximity to a town or city, are also recorded.[22]

The second source was data collected by volunteers during beach cleanups and reported to the Australian Marine Debris Initiative. The Australian Marine Debris Initiative organizes clean-up events and ongoing marine protection programs throughout Australia, allowing a way for interested people to become involved in removing marine debris throughout beaches in Australia. This organization provides a public record of all beach clean-ups reported, which includes the amount and percentage of each material found, including cloth, foam, glass and ceramic, metal, paper and cardboard, rubber, wood, and plastic.[23] The data from these cleanups differs from the data collected using the NOAA protocol because the entire beach is cleaned and recorded, rather than discrete portions.

Comparing marine debris from various locations can be difficult because a nationally or internationally standardized method of counting and recording marine debris on the shoreline has not been implemented. Due to the differences in the methods of recording and collecting debris, this study primarily examines the differences in the percentages in plastic debris between the two beaches, as plastic is regarded as one of the most harmful debris, as well as the longest lasting in the environment.[24] For the purposes of this study, each item of debris recorded was placed into one of the following eight categories: plastic and foam, cloth, glass and ceramic, metal, paper and cardboard, rubber, wood, and other materials. Plastic and foam were grouped together into one category because the majority of foam collected was in the form of Styrofoam. Styrofoam is

[22] Sarah Opfer, Courtney Arthur, and Sherry Lippiat, *NOAA Marine Debris Shoreline Survey Field Guide* (National Oceanic and Atmospheric Administration, 2012), 1-14.
[23] Australian Marine Debris Initiative, Public Data, available from http://www.tangaroablue.com/amdidb/reports.php
[24] *Current Research, Solution Strategies and Data Gaps* (Oakland: California Ocean Science Trust, 2011), 7-44.

a low density plastic, which contributes to the total amount of plastic pollution in the ocean harming marine organisms.[25]

Research

This research was based on the hypothesis that there is a difference between the average composition of plastic debris on beaches in Melbourne's Port Phillip Bay and San Francisco's San Francisco Bay Area. This hypothesis was formed because of the differences in public policy regarding beach debris in San Francisco and Melbourne, which likely has an effect on the amount of plastic pollution. In total, 6,616 pieces of debris were recorded from the portions of the beaches surveyed in the San Francisco Bay Area, shown in Appendix 1. These surveys comprised a total of 196 transects, each making up a five meter section of the one hundred meter beach survey site. The data collected about the amount of debris in each section can then be extrapolated to estimate the density of debris on the beach. Assuming each sample was representative, there were a total of 33,550 pieces of debris on these beaches when they were surveyed. Figure 3 shows the total composition by number of pieces of debris on beaches in the San Francisco Bay Area. The data for Figure 3 result from totaling the data from all the beaches surveyed in the San Francisco Bay Area. Plastics and foam clearly make up the majority of the marine debris, although other materials, known to be less harmful to marine life and faster to break down, make up nearly forty percent of the total marine debris found in the San Francisco Bay.

[25] Charlotte Stevenson, *Plastic Debris in the California Marine Ecosystem: A Summary of*

Figure 3: San Francisco Bay, Total Debris Composition

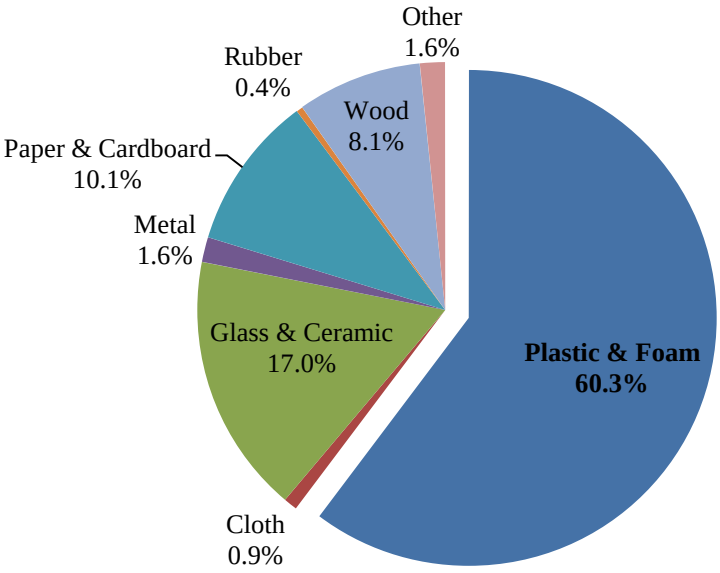
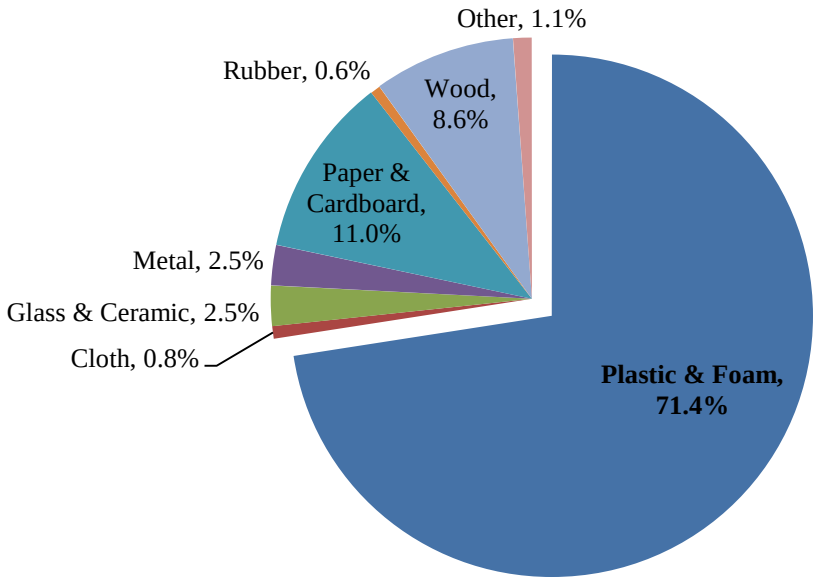


Figure 4 shows the <u>average</u> composition of marine debris on a beach in the San Francisco Bay Area, illustrating the difference between the total percentages for all beaches and the average percentages of each debris type for individual transects. On average, each beach had 137 debris items recorded from the sampled areas, which indicates the average amount of debris for each beach in its entirety was approximately 670 items of debris. This means that for each beach,

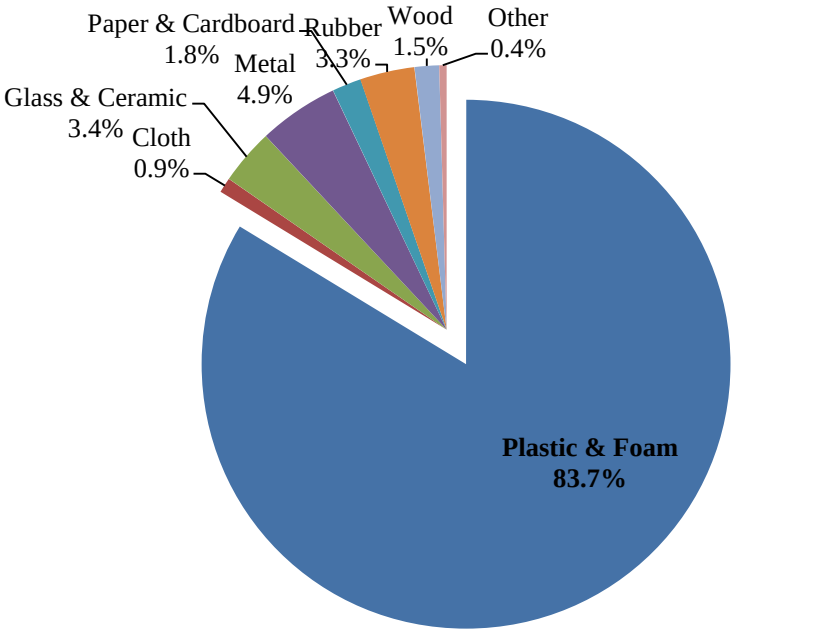
Figure 4: San Francisco Bay, Average Debris Composition



543 of the items found could be expected to be plastic debris. Figure 4 shows that the average beach actually has a larger amount of plastics in proportion to other materials than Figure 3 would suggest. Although certain beaches in the San Francisco Bay, such as Limantour Beach, have an extremely low percentage of plastic debris, beaches closer in proximity to the city of San Francisco often have a higher level of marine debris. Figure 4 represents what debris composition can be expected at an average beach in the San Francisco Bay Area.

The same type of data on beach debris composition was collected for beaches surveyed around Melbourne by volunteers with the Australian Marine Debris Initiative. A total of twenty-nine marine debris surveys were conducted in Melbourne's Port Phillip Bay region. From these surveys, 27,203 debris items were recorded and collected, 22,772 of which were plastics. Figure 5 shows the total composition of all marine debris recorded. This chart shows the total amount of debris from Port Phillip is higher than the worldwide average of 60 - 80% plastic debris.[26]

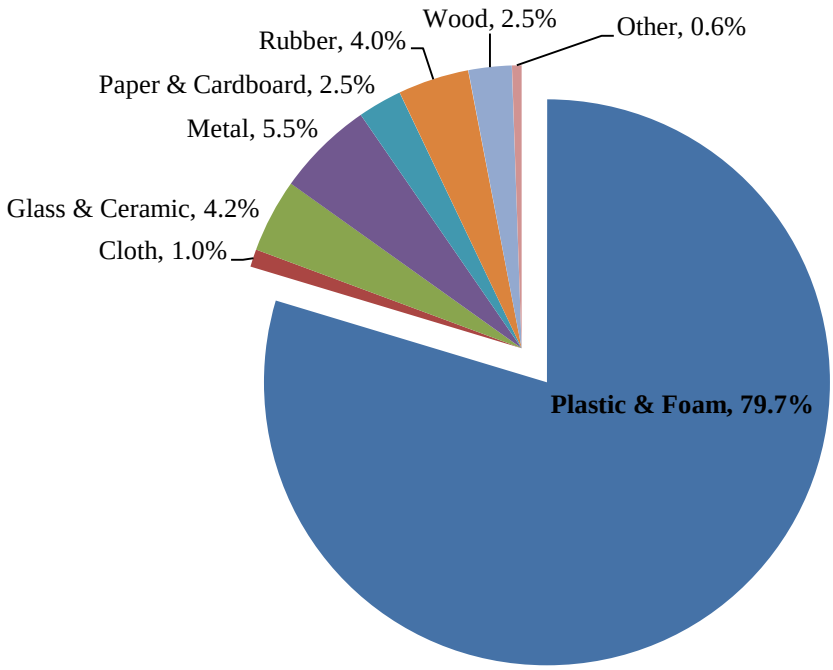
Figure 5: Port Phillip Bay, Total Debris Composition



[26] Stevenson, *Plastic Debris in the California Marine Ecosystem*, 1-3.

However, as with the San Francisco Bay, the average percentage of plastic debris on individual beaches differs from the total percentage. Figure 6 shows the average debris composition from the various beach surveys. Figure 6 shows that Port Phillip Bay is on the higher end of the range of the expected percentage of plastics, but looking at the composition of marine debris in terms of each beach's average shows that this region is below the 80% amount of marine debris that is at the upper end of what would be expected to be found worldwide. An average beach in Port Phillip Bay had approximate 940 items of debris recorded. From this estimation, it could be expected that each beach had 750 pieces of plastic.

Figure 6: Port Phillip Bay, Average Debris Composition



The differences between the average debris composition Melbourne's Port Phillip Bay and San Francisco's San Francisco Bay is statistically significant (t-value = 1.9706, df = 223, p-value=.0390). This provides support for the hypothesis that the true mean proportion of plastic debris by the percentage of pieces on beaches is not the same on Melbourne and San Francisco beaches.

Figure 7: Average % Plastic Debris, Confidence Intervals

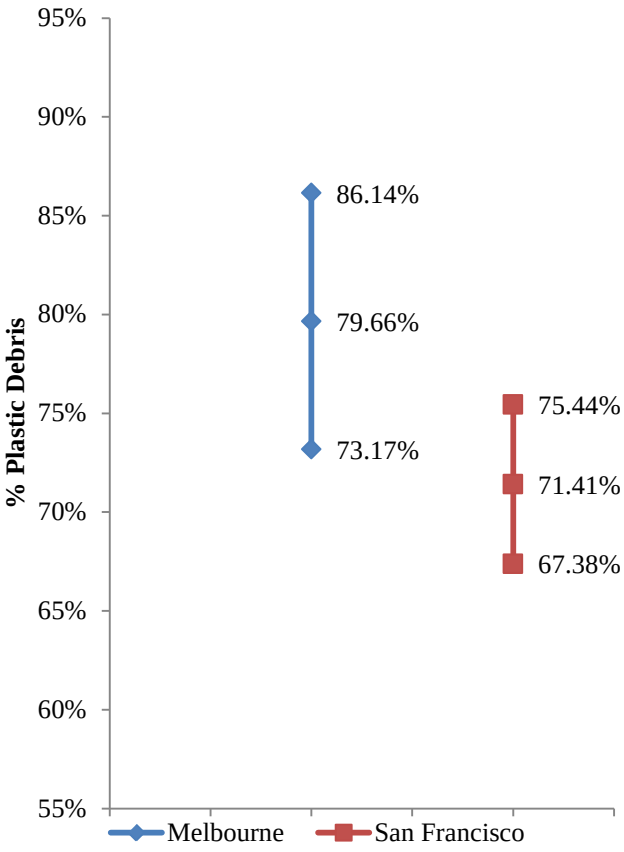


Figure 8: Average % Plastic Debris, Standard Error

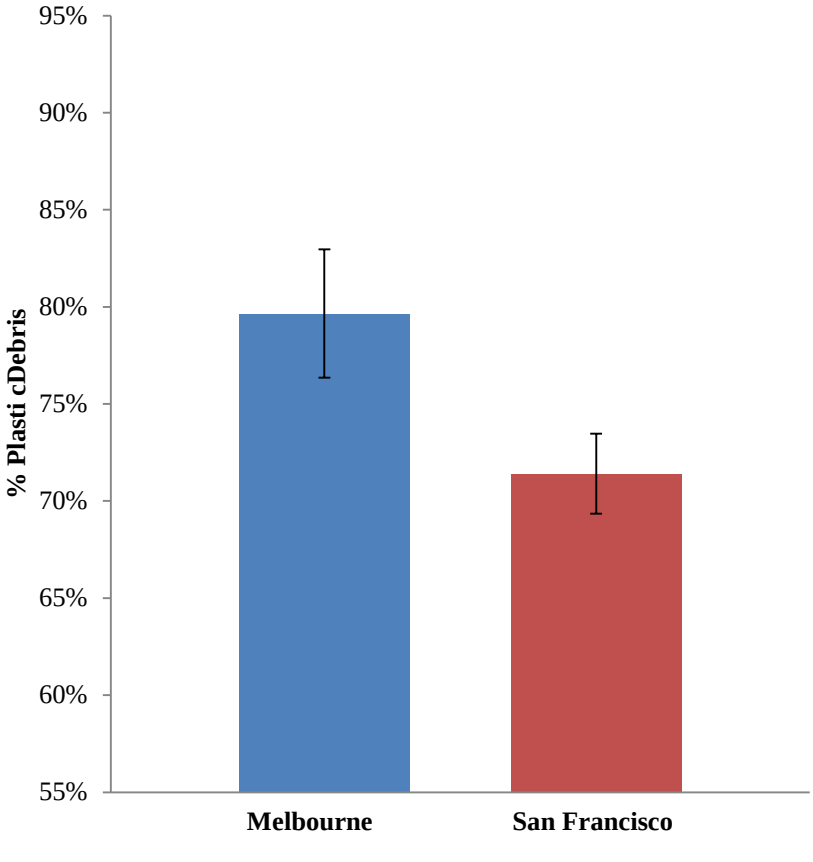


Figure 7 shows the mean percentage of plastic debris on individual beaches for each city, with a 95% confidence interval. Figure 8 shows the found mean percentage of plastic debris on beaches in Melbourne (standard deviation = 17.81, standard error = 3.31, n = 29) and San Francisco (standard deviation = 28.80, standard error = 2.06, n=196).

From Figures 7 and 8, it is clear that the average percent of plastic pollution on beaches around Melbourne and San Francisco differ. These results compare all beaches in the region, without controlling for the proximity to the cities or the pedestrian foot traffic. An interesting comparison can be made between looking at the debris on two beaches that are similar in these respects: St. Kilda Beach, located just outside the main city of Melbourne, and Crissy Field beach, located in the city of San Francisco. These beaches both have the heavy foot traffic associated with the thriving tourist industry in each of the cities, and they have been directly targeted through clean up and education efforts.

Figure 9: Crissy Field Beach, Total Debris Composition

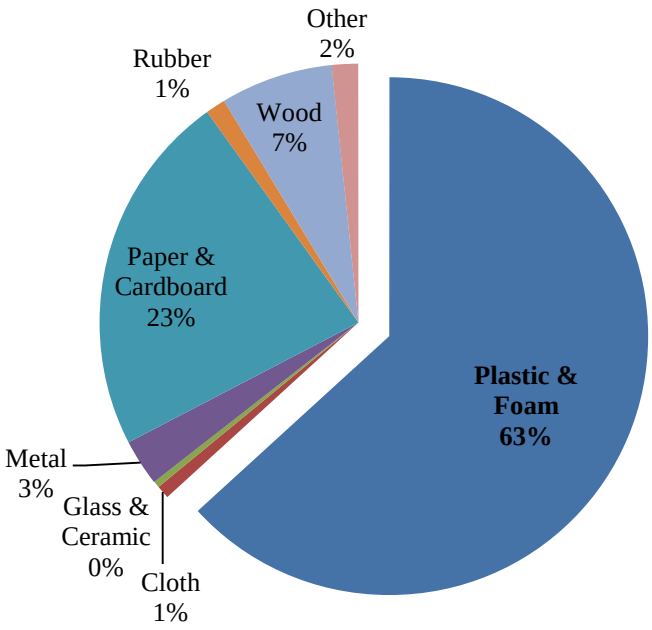


Figure 10: St. Kilda Beach, Total Debris Composition

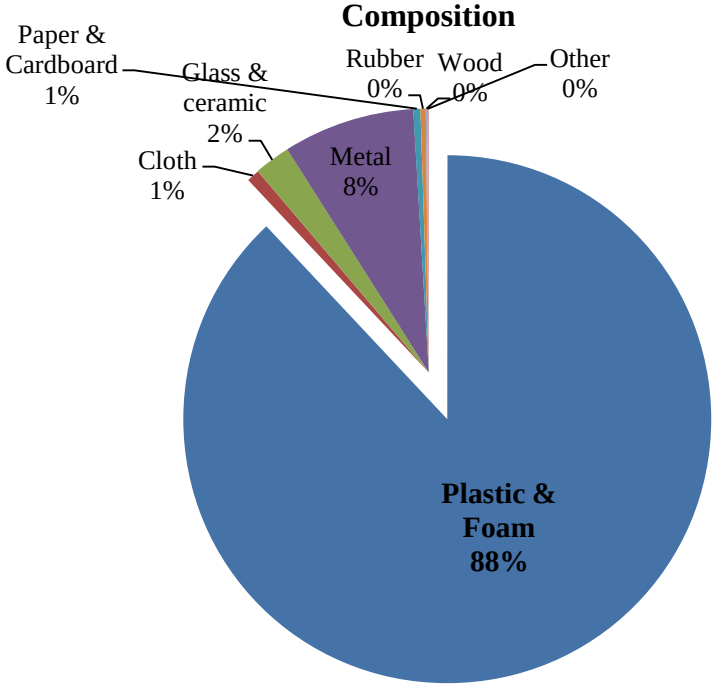


Figure 9 shows the composition at Crissy Field Beach in San Francisco. From the ten five meter sections surveyed, 242 pieces of debris were collected. Assuming the amount of debris found from the surveyed transects was representative of the entire beach, on average Crissy Field Beach had an average of 480 pieced of debris, 302 of which would be plastics. The most commonly found items of debris were unidentifiable plastic bits, making up 24.4 percent of the

total debris found, cigarette butts and filters, making up 14 percent, and Styrofoam bits making up 12.4 percent. Figure 10 shows the composition of debris at St. Kilda Beach, which is the closest and most accessible beach to the city of Melbourne. A total of 9,285 items were collected from the ten beach cleanups done of the St. Kilda Beach in its entirety by the Australian Marine Debris Initiative. On average the beach therefore contains 929 pieced of debris on it, 816 of which were plastics. The most commonly found items were cigarette butts and filters, making up 35 percent of the total debris found, foam insulation and packaging, making up 10 percent, and straws, confection stick, and plates, making up 9.3 percent. This is not a perfect comparison because the beaches are not completely identical, and outside factors such as independent beach clean ups or the skill level of the volunteers surveying can influence the amount of debris recorded. However, St. Kilda Beach overall has a higher amount of debris and a higher proportion of plastic.

The low level of plastic pollution found at Crissy Field beach is surprising, because the beach is located within San Francisco's city limits and it is a common tourist destination. The percentage of plastics at Crissy Field Beach is below the average percentage for beaches in the San Francisco Bay, and toward the lower end of the estimated percentage of plastic debris in the ocean overall,[27] while on St. Kilda beach, plastic and foam makes up 88 percent of the debris collected, putting it well over the average proportion of plastic debris in oceans around the world. St. Kilda Beach and Crissy Field Beach further reflect the differences between the levels of plastic pollution in San Francisco and Melbourne. Due to the fact that these are similar beaches, with similar amounts of traffic, the differences are likely come from each of the city's public policies.

[27] Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel, *Impacts of Marine Debris on Biodiversity*, 10-12.

Policy

Both San Francisco and Melbourne have recognized that marine debris, especially plastic debris, can be extremely harmful to marine ecosystems, and both have attempted to reduce the amount of plastic in their surrounding oceans through legislation. It is not just preserving biodiversity that has caused San Francisco and Melbourne to act on the rising levels of debris on beaches around the world.[28] The California marine economy is estimated to be a 46 billion dollar industry.[29] Australia, along with the greater Asia-Pacific Economic Cooperation (APEC), has estimated the negative effects of marine debris to cost the APEC region 1.265 billion dollars of the 207 billion dollar marine economy every year.[30] In order to preserve the marine economy and the quality of oceans, the United States, California, and especially San Francisco itself have undertaken several progressive steps toward significantly reducing the levels of plastic pollution resulting from recreational activities on its beaches.

The United States created a comprehensive oceans policy with the Oceans Act of 2000. This act was enacted to promote stewardship of ocean and coastal resources, protect marine environments from pollution, and expand public knowledge about oceans.[31] In order to achieve these goals and create cooperation between government agencies, the Oceans Act of 2000 created a Commission on Ocean Policy to produce a National Oceans Report.[32] This report includes the current state of the oceans and policy recommendations to improve the United

[28] Gregory, "Environmental implications of plastic debris," 2014-2018.
[29] "The Problem with Marine Debris."
[30] McIlgorm, Campbell, and Rule, *Understanding the Economic Benefits and Costs of Controlling Marine Debris in the APEC Region*, 13-20.
[31] "Information on the Oceans Act of 2000." U.S. Commission on Ocean Policy, last modified January 9, 2003. http://govinfo.library.unt.edu/oceancommission/documents/oceanact.html
[32] Hollings, Ernest F. "Legislative History of the Oceans Act of 2000." (Presented to the U.S. Senate to establish a Commission on Ocean Policy, March 29, 2000).

States' ocean policy. The Oceans Act appropriated $7.5 million to the Commission to complete its report.[33]

The Commission on Ocean Policy recommended that the National Oceanic and Atmospheric Administration, commonly known as NOAA, should be tasked with three specific functions, the first being management, the second being assessment, predictions, and operations, and the third being research and education. The Commission further recommended a renewed commitment to ocean research by increasing funding, as the United States significantly cut the funding to ocean research during the prior twenty-five years, as well as improved planning for research projects. Since no national monitoring system exists, the Commission recommended a joint effort by NOAA, the Environmental Protection Agency, and the U.S. Geological Survey to develop a monitoring system to encompass the federal, state, and local levels.[34] Finally, the Commission suggested in its report that NOAA, in conjunction with the United States' EPA, should expand its efforts to reduce marine debris, particularly through public outreach and education efforts, which can be facilitated by partnerships with local governments.[35]

The nation's primary oceanic agency, NOAA, was created in 1966 as a part of the Marine Resources and Engineering Development Act.[36] NOAA's mission is to "understand and predict changes in climate, weather, oceans, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources."[37] Studies done by NOAA have shown that only 32 percent of adults understand simple environmental

[33] "Information on the Oceans Act of 2000."
[34] U.S. Commission on Ocean Policy, an Ocean Blueprint for the 21st Century Final Report (Washington D.C.: United States Congress, 2004), 1-30.
[35] "Information of the Oceans Act of 2000."
[36] "A History of NOAA." NOAA, last updated June 8, 2006. http://www.history.noaa.gov/legacy/noaahistory_3.html
[37] "Chapter 4 – Strategic Planning – NOAA's Mission and Vision." NOAA, last modified November 5, 2013. http://www.ppi.noaa.gov/bom_chapter4_noaa_mission_and_vision/

issues, and far fewer show an understanding of more complex issues, such as the loss of biodiversity.[38] In 2003, the NOAA Education Council was formed to improve public knowledge about environmental issues.[39] Despite this national approach for educational efforts, the levels of marine debris have remained unchanged along the Pacific coast.[40]

On the state level, California has made several efforts to reduce marine debris through legislation. In 2006, the California Coastal Commission published an action plan to reduce land-based discharges of marine debris. The State Water Resource Control Board funded the California Coastal Commission to conduct research and create this report. The main points of the action plan included introducing additional trash receptacles to "hot spots" on beaches, where litter and debris commonly accumulate, enforcing littering laws, reducing the quantity of municipal waste, especially single-use products, and developing standards for environmentally preferable packaging.[41] The plan advocated for litter fees and taxes on products that were identified to contribute significantly to marine debris. California has already successfully used this technique to promote recycling beverage containers. Consumers pay a fee, known as the California Redemption Value, for every beverage container they purchase, which can be reimbursed by bringing the containers to a recycling center. This program has accounted for nearly 300 billion containers being recycled in California since 1987.[42] The California Coastal Commission stated that a tax or fee could provide permanent funding for a marine debris

[38] McIlgorm, Campbell, and Rule, *Understanding the Economic Benefits and Costs of Controlling Marine Debris in the APEC Region*, 247-254.
[39] "NOAA Education Council." NOAA, accessed March 20, 2014. http://www.oesd.noaa.gov/leadership/edcouncil/
[40] Christine A. Ribic, Seba B. Sheavly, David J. Rugg, and Eric S. Erdmann. "Trends in Marine Debris along the U.S. Pacific Coast and Hawai'i 1998–2007." *Marine Pollution Bulletin* 64.5 (2012): 994-1004.
[41] Miriam Gordon, *Eliminating Land-based Discharges of Marine Debris in California: A Plan of Action from The Plastic Debris Project* (California Coastal Commission, 2006), 9-12.
[42] "Beverage Container Recycling." CalRecycle, last modified February 14, 2014. http://www.calrecycle.ca.gov/bevcontainer/

program. This report advocated for legislative changes as well as an increase in education efforts to improve the overall quality of California's beaches.

From these recommendations, several legislative changes were made. An education effort has been made to address litter in California. The "Don't Trash California" campaign is a 22-month effort throughout the state to reduce trash and pollution, costing $6.5 million, currently in its early stages of implementation.[43] The state of California also began requiring grocery stores to take back and recycle plastic bags in 2006, as well as provide reusable bags for sale.[44] Over a million plastic bags from land-based sources enter the San Francisco Bay every year, making single-use plastic bags a major environmental concern in California.[45] From the 196 transects of beach surveyed, this study found 61 plastic bags, 53 of which were weathered from being in the oceans, washed back onto the shore by the tides, and 8 of which were fresh litter. If this sample was representative of the entire beach, there were actually 306 plastic bags on just the beaches surveyed in this study. Although a state wide "bag ban" has not been passed, several cities throughout the San Francisco Bay Area have either banned single-use plastic bags or are now taxing single-use plastic bags to incentivize consumers to use reusable bags and reduce the number of single-use plastic bags in the San Francisco Bay. If local initiatives in limiting the use of single-use plastic bags are successful, the number of plastic bags found on beaches should be decreasing over the next few years.

Cities throughout the San Francisco Bay Area have also implemented various additional methods to reduce the levels of marine debris resulting from land-based activities. The city of

[43] Gordon, *Eliminating Land-based Discharges of Marine Debris in California*, 35.
[44] Stevenson, *Plastic Debris in the California Marine Ecosystem*, 41-45.
[45] "Bay Area Bag and Styrofoam Bans." Save the Bay, last modified April 8, 2014. http://www.savesfbay.org/banmap

Oakland, in Alameda County, implemented a tax on fast food restaurants, which ranges from $230 to $3,815 per year depending on how much waste the restaurant is expected to create.[46] Nearly thirty percent of the jurisdictions in the San Francisco Bay Area have banned Styrofoam food containers, as Styrofoam pieces are another common material found on San Francisco beaches.[47] Storm drains are a common distributor of debris from land-based sources into oceans and rivers, as litter in storm drains flows directly to creeks and into the ocean. To reduce this distribution, San Francisco County has installed capture devices to meet the zero waste ordinance implemented by the San Francisco Regional Water Quality Board in 2009, aiming for 100 percent divergence of trash and debris from storm water by 2022.[48] Several other cities and counties in the San Francisco Bay Area, including Alameda County, Contra Costa County, Santa Clara County, and San Mateo have followed suit by implementing storm water permits, in order to regulate the discharge into creeks and meet reduction targets.[49]

Like the United Stated, Australia also has a history of legislation aimed to reduce marine debris at the federal, state, and local levels. Australia's Oceans Policy was approved in 1998. The goal of this policy was to exercise the rights of offshore resources while maintaining the biodiversity and sustainability of ocean environments.[50] Australia's ocean regions are very important, both economically and ecologically. The oceans surrounding Australia contribute approximately AU$70 billion (approximately US$65.8 billion) to the economy per year, making

[46] Gordon, *Eliminating Land-based Discharges of Marine Debris in California*, 38.
[47] "Bay Area Bag and Styrofoam Bans."
[48] Stevenson, *Plastic Debris in the California Marine Ecosystem*, 32-45.
[49] Gordon, *Eliminating Land-based Discharges of Marine Debris in California*, 18-20.
[50] Intergovernmental Oceanographic Commission, *National Ocean Policy*. 11-16.

up 14 percent of Australia's total annual GDP.[51] Ecologically, Australia is one of the world's most biologically diverse nations, and nearly 80 percent of the species found in marine environments are endemic, therefore not found anywhere else in the world. This policy established the National Oceans Ministerial Board of Commonwealth ministers as a governing body over the states. The states were required by this policy to make Regional Marine Plans, which identify the economic opportunities in the oceans as well as the current threats to ecosystem health.[52] These factors determine how resources can be used while maintaining a baseline for environmental quality.[53]

The Environment Protection and Biodiversity Conservation Act was passed in 1999, which listed marine debris as a key threatening process to marine life.[54] In 2009, the Australian Government published the *Threat Abatement Plan for the Impacts of Vertebrae Marine Life* under this act. This plan outlines a national approach to evaluating the existing policy's effectiveness, continuing marine animal recovery plans, and examining the effectiveness of the agreements with other nations with regard to marine debris.[55] Australia also implemented its National Waste Policy in 2009 to manage waste throughout the nation. The policy makers recognized that the level of waste being generated has been growing far more rapidly than recycling and reuse programs.[56] The National Waste Policy aims to reduce the generation of

[51] Donna Petrachenko "Australia's Oceans Policy: Ecologically Sustainable Development in the Marine Environment" (PowerPoint presented for Australian Government Department of Environment and Water Resources).
[52] Edward N. Eadie, "Evaluation of *Australia's Oceans Policy* as an example of public policy-making in Australia" *Maritime Studies* (2001): 1-13.
[53] Intergovernmental Oceanographic Commission, *National Ocean Policy*, 14.
[54] "Marine Debris." Australian Government Department of the Environment, accessed March 7, 2014. http://www.environment.gov.au/topics/marine/marine-pollution/marine-debris
[55] "Marine Debris."
[56] "About National Waste Policy." Australian Government Department of the Environment, accessed March 7, 2014. http://www.environment.gov.au/topics/environment-protection/national-waste-policy/about-policy

waste and ensure that all waste is disposed in an environmentally safe manner. The Australian government has worked closely with several regional groups, such as the Coral Triangle Initiate and the Asia Pacific Economic Cooperation.[57] These groups have recognized that one country's policies can influence neighboring countries, so region groups have come together to make comprehensive ocean policies in order to reduce marine debris in the region as a whole.[58]

The state of Victoria, where Melbourne is located, has passed some legislation regarding coastal management. For example, the Coastal Management Act was passed in 1995, which created the Victorian Costal Council. This council provides a framework strategy for planning and giving attention to local issues.[59] Although several action plans have been made for various coastal regions in Victoria, marine debris is not cited as an issue on Victoria's coasts.[60] In the Port Phillip Bay Environmental Management Plan, published by the state of Victoria's Department of Natural Resources and Environment, litter is mentioned as one of eight threats to the marine environment in Port Phillip Bay. However, the report lists policies regarding litter on beaches as being under the responsibility of the local government.[61] With respect to managing the marine environment, the main focus of the state government in Port Phillip Bay is monitoring the nutrients in Port Phillip Bay and reducing marine pests.[62] The Environmental Protection

[57] "Marine Debris."
[58] Eadie, "Evaluation of *Australia's Oceans Policy*," 1-13.
[59] "Coastal Planning." Coastlinks Victoria, last modified April 8, 2012. http://www.coastlinks.vic.gov.au/coastalplans.htm
[60] Central Coastal Board, "Waterfront Geelong Coastal Action Plan 1998 Five-Year Review Report 2004," (2004): 1-22.
[61] State of Victoria Department of Natural Resources and Environment, *Port Phillip Bay Environmental Management Plan: Background Information* (East Melbourne: State of Victoria, 2002), 3-57.
[62] "Port Phillip Bay." Department of Environment and Primary Industries, last modified January 22, 2014. http://www.depi.vic.gov.au/forestry-and-land-use/coasts/marine/bays-inlets-estuaries-and-lakes/port-phillip-bay

Agency of Victoria has made significant efforts at improving water quality, although their focus is on monitoring toxins in the water, such as lead and mercury, and not on removing debris.[63]

In Port Phillip Bay, cities allocated AU$3.5 million to operating a mechanical cleaning system daily during the summer months on popular beaches, such as St. Kilda Beach. During winter months the beach is cleaned once per week. This beach cleaner picks up cigarette butts, small pieces of glass, and any other litter left on the beach. According to the city of Port Phillip, a large portion of the identifiable litter on its beaches is cigarette butts. Due to this, the Port Phillip Bay region launched the "No Cuts, No Butts" campaign in 2010. This campaign was aimed toward educating the public that glass and cigarettes are not allowed on beaches. The campaign has been effective in educating the public, and since its implementation the levels of cigarettes, glass, and litter on the beaches has dramatically decreased.[64] This legislation was likely successful because over half the debris in Port Phillip Bay is directly generated from littering at the site or runoff from storm water, according to a study done by Tangaroa Blue Ocean Care Society.[65] The "No Cuts No Butts" campaign also worked to educate the public that litter left on streets can be washed into storm drains, which directly pollutes the bay. This portion of the campaign aimed to address the litter entering the bay from over 300 storm drains that empty into the Port Phillip Bay from around the region. The Port Phillip Bay, similar to the San

[63] "Monitoring Port Phillip Bay." EPA Victoria, last modified August 17, 2012. http://www.epa.vic.gov.au/our-work/monitoring-the-environment/monitoring-port-phillip-bay
[64] "No Cuts No Butts." City of Port Phillip, accessed February 4, 2014. http://www.portphillip.vic.gov.au/no_cuts_no_butts.htm
[65] Heidi Taylor and Wally Smith, *2010-11 Victorian Surf Coast: Marine Debris Project Report* (Port Douglas: Tangaroa Blue Ocean are Society, 2011), 2-8.

Francisco Bay, has installed many litter traps at the end of drains to keep debris from entering the bay.[66]

Discussion

In this study, it is important to recognize that there are several sources for potential error. The data collected in Australia came primarily from volunteer efforts. Although this approach can be a quick and effective way to clean up a beach, the data can be less reliable than data collected with a standardized protocol, such as the NOAA protocol for recording marine debris. A 1998 study estimated that volunteers, who collected over 8,000 pieces of debris, left nearly 68,000 marine debris items on the shore. The majority of this debris, however, was extremely small plastic pellets (<5mm) that require a sieve to remove.[67] It is unlikely that researchers using the standardized NOAA protocol would have collected this small debris in surveys either, as NOAA does not use a sieve and relies on the naked eye to spot debris. In addition, each piece of debris is counted the same regardless of its size or weight in both the NOAA protocol and the surveys done through the Australian Marine Debris Initiative. In a more in-depth, future study, the size and weight of each item of debris should be taken into account when they are recorded. Although beach surveys are by no means a perfect system for determining the level of marine debris or plastic pollution, nevertheless they do provide a valuable general understanding of the state of the oceans and composition of debris in various areas.

Similarly, the level of debris on beaches is not only variable because of the amount of litter entering the ocean, but also because of natural events such as strong winds, tides, or storms. One study, for example, found that in the winter, especially after storm events, there was an

[66] "Stormwater Pollution." City of Port Phillip, accessed January 28, 2014. http://www.portphillip.vic.gov.au/stormwater_pollution.htm
[67] Stevenson, *Plastic Debris in the California Marine Ecosystem*, 2-5.

increase in the amount of litter, fertilizer pellets, and plastics debris on beaches in close proximity to rivers.[68] This increase in beach debris does not necessarily indicate a change in human behavior. The surface currents can change velocity and direction seasonally, and the circulation can change in a matter of days.[69] Because of this, the debris recorded on a beach for any given day can be highly variable. Over 80 percent of the debris found on beaches in the San Francisco Bay Area was recorded as being "weathered," indicating that it had been exposed to natural elements such as wind or water. It is possible that some of this debris was transported from other beaches through ocean currents, or that it originated from inland sources outside the San Francisco Bay Area, transported by rivers emptying into the bay. When analyzing the data and the effectiveness of policy, the variability of the ocean currents and weather is important to consider.

Another potential source of error in analyzing the effectiveness in legislation can come from looking at the percentages of plastic pollution on beaches. This study focuses on the percentage of plastic marine debris on beaches currently. This allows for an analysis of the health of the beach, regardless of the size of the beach or the regularity of community beach cleanups. However, this can create a false sense of success or failure of public policies if the level of other materials is not held constant. If the level of other debris is decreasing more rapidly than the level of plastics, it will appear from the percentage of plastics on a beach that the level of plastic debris is increasing. Similarly, if a larger quantity of other debris is being discarded on the beaches, the proportions of plastics will artificially fall. Nevertheless, most legislation regarding beach debris advocates a reduction in all litter and debris, while especially focusing on reducing

[68] C. Rosevelt, M. Los Huerton, C. Garza, and H.M. Nevins, "Marine Debris in Central California: Quantifying type and abundance of beach litter in Monterey Bay, CA," *Marine Pollution Bulletin*, 2013 (in press).
[69] Rosevlet et al "Marine Debris."

plastics. The majority of the other debris decompose within a matter of weeks to a few years, while plastics can take hundreds of years to completely break down, releasing toxins into the water during this process.[70] Assuming the levels of non-plastic debris is kept at least at a constant level, a reduction in the percentage in plastics will account for an overall improvement in the quality of the beach.

In spite of these sources of error, from the data collected, it is clear there is a difference between the levels of plastic pollution on the beaches in Port Phillip Bay compared to the San Francisco Bay. However, from the policy analysis, the goals of the federal programs are extremely similar. Australia and the United States both wish to utilize offshore resources while maintaining a sustainable marine environment. At the local level, several of the same tools have been implemented, such as installing equipment in storm drains to stop land-based debris from entering the ocean. However, merely introducing the equipment is not enough. San Francisco, as well as several surrounding counties, set benchmark goals to eventually lead to 100 percent divergence of storm water debris away from the ocean. Implementing these standards allow for the constant monitoring and improving of the efficiency of litter traps. This policy has been very successful in the San Francisco Bay Area, and might also be beneficial if implemented in the Port Phillip Bay region.

Melbourne and the Port Phillip Bay lack the state-wide support from Victoria that San Francisco has been given by California and the California Coastal Commission. The California Coastal Commission has provided support for local initiatives to reduce plastic debris on San Francisco's beaches, and it has provided independent cities and counties with a unifying force to continue these local initiatives to the state level. Marine debris is not isolated to one area; it can

[70] Stevenson, *Plastic Debris in the California Marine Ecosystem*, 3-

be easily moved from one beach area to another by the ocean currents. Because of this, having a unified state initiative to reduce plastic in the ocean is critical, as this support will allow for cleaner beaches and continued improvement on reducing the level of plastic pollution and beach debris. California policies that reduce the amount of waste output or encourage recycling, such as the California Redemption Value for plastic beverages, ultimately help keep all beaches cleaner, as they incentivize residents to properly dispose of waste. These efforts can be furthered in the future by improving land waste management policies, as this has been shown to have a direct effect on the levels of litter and debris as whole entering oceans. Australia has similarly created a coalition with neighboring countries, such as Malaysia and Indonesia, to create public policies that keep the ocean cleaner for all countries involved.[71] Having a state governing board advocating for reducing beach debris, especially plastics, can organize and incentivize individual communities to unite toward a common goal of reducing the level of marine debris. The California Coastal Commission is not a perfect agency. State funding for the Coastal Commission has decreased by 26 percent since 1980 when accounting for inflation, largely due to California's economic decline beginning in 2008.[72] However, having this underlying infrastructure has helped to unite many cities, as well as show that California is interested in making changes at the state level. Nevertheless, not every issue brought before the state that would reduce the levels of plastic debris off the coast has passed; both statewide bans on Styrofoam food containers, single-use plastic bags, and plastic bottle caps have failed recently in California.[73]

[71] "Marine Debris."
[72] "California Coastal Commission." All Gov California, accessed April 28, 2014. http://www.allgov.com/usa/ca/departments/natural-resources-agency/california_coastal_commission?agencyid=155
[73] Stevenson, *Plastic Debris in the California Marine Ecosystem*, 41-50.

Perhaps because of the initial efforts by the state and the California Coastal Commission to reduce marine debris, cities throughout California, and especially surrounding the San Francisco Bay Area, have been far more progressive in implementing city ordinances in order to reduce plastic pollution than the cities surrounding Port Phillip Bay. Although the single-use plastic bag ban did not pass at the state level, nearly two thirds of the people in the San Francisco Bay Area are living under some form of a bag ban through city or county ordinances.[74] These cooperative policies between cities have benefitted the San Francisco Bay as a whole, which is reflected in the lower level proportions of plastic debris on San Francisco Bay Area beaches.

Although increasing educational efforts have been in several action plans, the San Francisco Bay Area has not executed any government policies to educate the public or the region's youths. Public education efforts have the effect of creating a sense of public responsibility for beaches, which can reduce the amount of littering.[75] Several non-profit organizations throughout the San Francisco Bay Area have worked toward educating the public, although their reach can be far more limited than the government's. Port Phillip Bay is an example of an extremely successful campaign that was able to significantly reduce the marine debris in this region. The "No Cuts, No Butts" campaign showed how effective simple education can be. Unlike a beach cleanup, which removes trash retrospectively, education has the potential to stop littering from occurring on numerous occasions in the future. San Francisco has been lacking in this section of public policy, and it could likely benefit by following Melbourne's example of educating the public.

[74] "Bay Area Bag and Styrofoam Bans."
[75] Ta-Kang Liu, Meng-Wei Want, and Ping Chen, "Influence of Waste Management Policy on the Characteristics of Beach Litter in Kaohsiung, Taiwan," *Marine Pollution Bulletin* 72 (2013), 99- 105.

Conclusions

At first glance, the San Francisco Bay Area and Melbourne's Port Phillip Bay appear extremely similar. Although these cities parallel each other in many ways, such as foot traffic and size, their public policies set them apart in terms of ocean cleanliness. Both San Francisco and Melbourne have implemented a variety of policies in order to address the rising issue of marine debris. Although Melbourne's Port Phillip Bay overall may have had a higher proportion of plastic debris than the San Francisco Bay, some of their policies have been extremely effective, especially in regards to their educational programs. Port Phillip Bay showed dramatic decreases in local litter after their "No Cuts, No Butts" Campaign, which is something that could benefit California. However, the still high levels of plastic pollution on both San Francisco and Melbourne beaches make it clear there are additional changes to be made. Each city has had their own successes and failures with the various policies they have attempted to implement. Through an analysis of the public policy in each of the regions, the most successful policies stand out. From this analysis of the data and the policies, the importance of having an overarching governing body, whether it is a state of federal agency, to unify coastal regions and education efforts is extremely clear. Adopting a combination of the policies implemented in San Francisco and Melbourne will allow, potentially, the most effective program for reducing marine debris and plastic pollution.

Appendix 1

Trip ID	Location	Date	Plastic & Foam	Cloth	Glass & Ceramic	Metal	Paper & Cardboard	Rubber	Wood	Other
LS1	South Limantour T1	3/27/ 2011	17	0	0	0	0	0	0	0
LS1	South Limantour T2	3/27/ 2011	34	0	0	0	0	0	0	0
LS1	South Limantour T3	3/27/ 2011	37	0	0	0	0	0	0	0
LS1	South Limantour T4	3/27/ 2011	16	0	0	0	0	0	0	0
L1	Limantour T1	3/28/ 2011	20	0	0	0	0	0	0	0
L1	Limantour T2	3/28/ 2011	16	0	0	0	0	0	0	0
L1	Limantour T3	3/28/ 2011	17	0	0	0	0	0	0	0
L1	Limantour T4	3/28/ 2011	19	0	0	1	0	0	0	0
SB1	S Beach, W Trail T1	4/10/ 2011	61	0	0	0	0	0	0	0
SB1	S Beach, W Trail T2	4/10/ 2011	25	0	0	0	0	0	0	0
SB1	S Beach, W Trail T3	4/10/ 2011	14	0	2	0	0	0	0	0
SB1	S Beach, W Trail T4	4/10/ 2011	51	0	0	0	0	0	0	0
D1	Drakes W T1	4/21/ 2011	6	0	0	0	0	0	0	0
D1	Drakes W T2	4/21/ 2011	44	0	0	0	0	0	0	0
D1	Drakes W T3	4/21/ 2011	195	0	0	0	0	0	0	0
D1	Drakes W T4	4/21/ 2011	17	0	0	0	0	0	0	0
D2	Drakes W1 T1	5/6/2 011	0	0	0	0	0	0	0	0
D2	Drakes W1 T2	5/6/2 011	2	0	0	0	0	0	0	0
D2	Drakes	5/6/2	1	0	0	0	0	0	0	0

	W1 T3	011								
D2	Drakes W1 T4	5/6/2011	2	0	0	0	0	0	0	0
LS2	South Limantour T1	6/22/2011	16	0	0	0	1	0	0	0
LS2	South T2Limantour	6/22/2011	10	0	0	1	1	0	0	0
LS2	South Limantour T3	6/22/2011	1	0	1	0	0	0	0	0
LS2	South Limantour T4	6/22/2011	1	0	0	0	0	0	0	0
AR 1	Arch Rock South	6/30/2011	2	0	0	0	0	0	0	0
SB2	South Beach T1	6/30/2011	7	0	0	0	0	0	0	0
SB2	South Beach T2	6/30/2011	18	0	0	0	0	0	0	0
SB2	South Beach T3	6/30/2011	21	0	0	0	0	0	0	0
SB2	South Beach T4	6/30/2011	6	0	0	0	0	0	0	0
P1	Palomarin 2nd cave T1	7/1/2011	25	0	0	0	0	0	0	0
P1	Palomarin T2	7/1/2011	20	1	0	1	0	0	0	0
P1	Palomarin T3	7/1/2011	17	1	0	0	0	0	0	0
P1	Palomarin T4	7/1/2011	13	0	0	0	0	0	0	0
	Callejones, North Love, Random,Big Wash South		149	9	1	0	0	0	0	0
	Callejones, Middle N Love		33	0	0	0	0	0	0	0
	North, north Callejones Cove		16	0	0	0	0	0	0	0
L2	Limantour North @ trailhead T1	7/26/2011	12	0	0	0	2	0	0	0

L2	Limantour North @ trailhead T2	7/26/ 2011	20	1	0	0	1	0	0	0
L2	Limantour North @ trailhead T3	7/26/ 2011	12	0	0	0	1	0	0	0
L2	Limantour North @ trailhead T4	7/26/ 2011	11	1	0	0	2	0	0	0
SB3	South Beach @ antenna T1	12/30 /2011	23	0	0	0	0	0	0	0
SB3	South Beach @ antenna T2	12/30 /2011	36	0	0	0	5	0	5	0
SB3	South Beach @ antenna T3	12/30 /2011	35	0	0	0	4	0	0	0
SB3	South Beach @ antenna T4	12/30 /2011	21	0	0	0	0	0	0	0
D3	Drakes Beach T1	12/30 /2011	0	0	0	0	1	0	0	0
D3	Drakes Beach T2	12/30 /2011	6	0	0	0	2	0	0	0
D3	Drakes Beach T3	12/30 /2011	6	0	0	3	3	0	0	0
D3	Drakes Beach T4	12/30 /2011	2	0	0	0	0	0	0	0
CC1	Coast Camp South T1	12/29 /2011	9	0	0	0	0	1	0	0
CC1	Coast Camp South T2	12/29 /2011	3	0	0	1	1	0	0	0
CC1	Coast Camp South T3	12/29 /2011	3	0	0	0	0	0	0	0
CC1	Coast Camp South T4	12/29 /2011	3	0	0	0	0	0	0	0
B1	Baker Beach T1	12/28 /2011	19	0	0	0	3	0	0	0

B1	Baker Beach T2	12/28 /2011	13	0	2	2	4	0	0	0
B1	Baker Beach T3	12/28 /2011	3	0	0	2	6	0	0	0
B1	Baker Beach T4	12/28 /2011	12	0	1	0	6	0	1	0
CF1	Crissy Field East Lot T1	12/28 /2011	13	0	0	2	6	0	0	1
CF1	Crissy Field East Lot T2	12/28 /2011	17	0	0	2	5	0	0	0
CF	Crissy Field East Lot T3	12/28 /2011	48	0	0	3	19	0	3	0
CF	Crissy Field East Lot T4	12/28 /2011	0	0	0	0	0	0	0	0
D4	Drakes Beach T1	10/31 /2011	1	0	0	0	0	0	0	0
D4	Drakes Beach T2	10/31 /2011	4	0	0	0	0	0	0	0
D4	Drakes Beach T3	10/31 /2011	15	0	0	1	5	0	0	0
D4	Drakes Beach T4	10/31 /2011	2	0	0	0	0	0	0	0
K1	Kehoe north @ rocks/cliff T1	10/31 /2011	21	0	0	0	0	0	0	0
K1	Kehoe north @ rocks/cliff T2	10/31 /2011	15	0	0	0	1	0	0	0
K1	Kehoe north @ rocks/cliff T3	10/31 /2011	4	0	0	0	0	0	0	0
K1	Kehoe north @ rocks/cliff T4	10/31 /2011	8	0	0	0	0	0	0	0
K2	Kehoe North Pt North T1	10/2/ 2011	52	0	0	0	0	0	0	0
K2	Kehoe North Pt North T2	10/2/ 2011	4	0	0	0	0	0	0	0
K2	Kehoe North Pt	10/2/ 2011	6	0	0	0	0	0	0	0

	North T3									
K2	Kehoe North Pt North T4	10/2/2011	18	0	0	0	1	0	0	0
L3	Limantour North T1	11/20/2011	12	0	0	0	0	0	0	0
L3	Limantour North T2	11/20/2011	5	0	0	0	0	0	0	0
L3	Limantour North T3	11/20/2011	4	0	0	0	1	0	0	0
L3	Limantour North T4	11/20/2011	10	0	0	0	0	0	0	0
CC2	Coast Camp South T1	8/18/2011	2	0	0	0	0	0	0	0
CC2	Coast Camp South T2	8/18/2011	4	0	0	0	0	0	0	0
CC2	Coast Camp South T3	8/18/2011	7	0	0	0	0	0	0	0
CC2	Coast Camp South T4	8/18/2011	2	0	0	0	2	0	0	0
FP1	Ferry Point Beach (in channel) T1	1/14/2012	27	0	427	1	0	0	0	0
FP1	Ferry Point Beach (in channel) T2	1/14/2012	97	0	150	1	11	1	0	0
FP1	Ferry Point Beach (in channel) T3	1/14/2012	64	0	172	1	6	0	9	0
FP1	Ferry Point Beach (in channel) T4	1/14/2012	52	0	334	0	4	1	2	0
LS3	Limantour South T1	11/20/2011	19	0	0	1	1	1	0	1
LS3	Limantour South T2	11/20/2011	6	1	0	0	4	0	0	0
LS3	Limantour South T3	11/20/2011	6	0	0	0	1	0	0	0

LS3	Limantour South T4	11/20/2011	0	0	0	7	0	0	0	0
P2	Palomarin North Cove @ log/slid T1	11/12/2011	87	3	0	0	0	0	0	0
P2	Palomarin North Cove @ log/slid T2	11/12/2011	18	2	0	1	0	0	0	0
P2	Palomarin North Cove @ log/slid T3	11/12/2011	30	3	0	0	0	0	0	0
P2	Palomarin North Cove @ log/slid T4	11/12/2011	15	0	0	0	0	0	0	1
L4	Limantour main parking, south of trail exit T1	1/26/2012	12	0	1	0	2	0	0	0
L4	Limantour main parking, south of trail exit T2	1/26/2012	11	0	0	1	0	0	1	0
L4	Limantour main parking, south of trail exit T3	1/26/2012	6	0	0	0	2	1	2	0
L4	Limantour main parking, south of trail exit T4	1/26/2012	10	0	0	1	0	0	0	0
P3	Palomarin T1	1/29/2012	30	2	1	0	1	0	26	0
P3	Palomarin T2	1/29/2012	42	1	0	2	0	0	46	0

P3	Palomarin T3	1/29/2012	25	0	0	0	0	0	35	0
P3	Palomarin T4	1/29/2012	39	0	0	0	1	0	14	0
D5	Drakes T1	2/2/2012	16	0	0	0	0	0	2	0
D5	Drakes T2	2/2/2012	21	0	0	0	0	0	3	0
D5	Drakes T3	2/2/2012	48	0	0	0	1	0	1	0
D5	Drakes T4	2/2/2012	5	0	0	0	0	0	0	0
RB1	Rodeo Beach T1	3/30/2012	20	0	0	0	0	0	2	0
RB1	Rodeo Beach T2	3/30/2012	9	0	0	0	0	0	10	0
RB1	Rodeo Beach T3	3/30/2012	16	0	0	0	2	0	12	0
RB1	Rodeo Beach T4	3/30/2012	5	0	0	0	0	0	8	1
S1	Stinson Beach T1	4/3/2012	22	0	0	1	4	1	0	0
S1	Stinson Beach T2	4/3/2012	17	0	3	0	14	0	3	1
S1	Stinson Beach T3	4/3/2012	27	0	1	0	15	1	1	1
S1	Stinson Beach T4	4/3/2012	25	0	0	3	16	1	4	0
LM1	Linda Mar Beach T1	4/21/2012	36	0	0	0	3	0	7	2
LM1	Linda Mar Beach T2	4/21/2012	28	0	3	0	10	0	3	0
LM1	Linda Mar Beach T3	4/21/2012	41	2	9	0	5	0	8	2
LM1	Linda Mar Beach T4	4/21/2012	0	0	0	0	0	0	0	0
SB4	South Beach T1	4/7/2012	8	0	0	0	0	0	0	0
SB4	South Beach T2	4/7/2012	0	0	0	0	0	0	1	0
SB4	South Beach T3	4/7/2012	5	0	0	0	0	0	0	0
SB4	South Beach T4	4/7/2012	9	0	0	0	0	0	0	0
D6	Drakes Beach T1	4/7/2012	21	0	0	0	0	0	0	0
D6	Drakes Beach T2	4/7/2012	7	0	1	0	0	0	0	0
D6	Drakes Beach T3	4/7/2012	80	1	0	0	1	0	3	1

D6	Drakes Beach T4	4/7/2012	11	0	0	0	0	0	5	2
S2	Stinson Beach T1	5/7/2012	18	1	1	1	26	1	1	2
S2	Stinson Beach T2	5/7/2012	71	1	0	1	18	0	2	1
S2	Stinson Beach T3	5/7/2012	35	1	1	2	15	3	1	0
S2	Stinson Beach T4	5/7/2012	35	1	0	1	21	0	2	1
LS4	Limantour South T1	5/8/2012	20	0	0	1	3	0	0	1
LS4	Limantour South T2	5/8/2012	6	0	0	1	5	0	0	0
LS4	Limantour South T3	5/8/2012	7	0	0	0	0	0	1	0
LS4	Limantour South T4	5/8/2012	8	1	0	0	0	0	0	0
L5	Limantour North T1	5/8/2012	24	0	0	2	0	0	0	0
L5	Limantour North T2	5/8/2012	30	0	0	0	1	0	1	1
L5	Limantour North T3	5/8/2012	32	0	0	0	1	0	2	1
L5	Limantour North T4	5/8/2012	9	0	0	0	2	0	1	2
CF2	Crissy Field T1	5/21/2012	14	1	0	3	5	1	0	1
CF2	Crissy Field T2	5/21/2012	31	1	0	0	12	0	1	0
CF2	Crissy Field T3	5/21/2012	22	0	0	0	8	0	1	0
CF2	Crissy Field T4	5/21/2012	0	0	0	0	0	0	0	0
B2	Baker Beach T1	5/21/2012	8	0	0	3	2	0	7	0
B2	Baker Beach T2	5/21/2012	3	1	0	4	7	0	0	0
B2	Baker Beach T3	5/21/2012	12	0	0	1	11	0	15	0
B2	Baker Beach T4	5/21/2012	8	0	0	4	11	0	2	0
K3	Kehoe Beach T1	5/22/2012	46	0	0	1	0	0	6	0
K3	Kehoe Beach T2	5/22/2012	33	0	1	2	0	0	0	0
K3	Kehoe Beach T3	5/22/2012	3	0	0	0	1	0	1	0
K3	Kehoe Beach T4	5/22/2012	26	0	0	0	0	0	0	0

RB2	Rodeo Beach T1	6/13/2012	12	2	0	0	0	0	5	1
RB2	Rodeo Beach T2	6/13/2012	25	1	0	0	2	1	8	0
RB2	Rodeo Beach T3	6/13/2012	4	0	0	0	0	0	5	0
RB2	Rodeo Beach T4	6/13/2012	3	0	0	0	2	0	2	0
CC3	Coast Camp T1	6/23/2012	5	0	0	2	0	0	2	0
CC3	Coast Camp T2	6/23/2012	0	0	0	0	0	0	5	0
CC3	Coast Camp T3	6/23/2012	2	0	0	0	0	0	3	0
CC3	Coast Camp T4	6/23/2012	12	0	0	0	1	0	4	0
D7	Drakes Beach T1	6/26/2012	0	0	0	0	1	0	0	0
D7	Drakes Beach T2	6/26/2012	1	0	0	0	0	0	1	0
D7	Drakes Beach T3	6/26/2012	2	0	0	0	1	0	0	0
D7	Drakes Beach T4	6/26/2012	4	0	0	0	2	0	1	0
SB5	South Beach T1	6/26/2012	9	0	0	0	0	0	0	0
SB5	South Beach T2	6/26/2012	3	0	0	0	0	0	0	0
SB5	South Beach T3	6/26/2012	1	0	0	0	0	0	0	0
SB5	South Beach T4	6/26/2012	2	0	0	0	0	1	0	0
CC A1	Crab Cove Alameda T1	6/28/2012	123	6	2	0	8	3	8	1
CC A1	Crab Cove Alameda T2	6/28/2012	18	0	1	0	2	3	4	0
CC A1	Crab Cove Alameda T3	6/28/2012	40	2	2	0	2	0	5	0
CC A1	Crab Cove Alameda T4	6/28/2012	110	1	11	0	10	2	11	0
S3	Stinson Beach T1	7/3/2012	37	1	0	6	18	0	2	2
S3	Stinson Beach T2	7/3/2012	16	4	0	3	11	0	2	3
S3	Stinson Beach T3	7/3/2012	44	0	0	11	42	1	0	1

S3	Stinson Beach T4	7/3/2012	33	1	6	5	12	0	1	0
P4	Palomarin T1	7/4/2012	28	0	0	0	1	0	31	0
P4	Palomarin T2	7/4/2012	16	0	0	0	0	0	19	0
P4	Palomarin T3	7/4/2012	7	0	0	0	0	0	41	0
P4	Palomarin T4	7/4/2012	16	0	0	0	0	0	39	0
CF3	Crissy Field T1	7/17/2012	8	0	0	0	8	0	6	1
CF3	Crissy Field T2	7/17/2012	13	0	1	0	1	0	8	0
CF3	Crissy Field T3	7/17/2012	15	0	0	0	4	2	1	1
CF3	Crissy Field T4	7/17/2012	20	0	0	0	6	0	0	0
B3	Baker Beach T1	7/17/2012	5	0	0	3	7	0	0	1
B3	Baker Beach T1	7/17/2012	4	0	0	1	15	0	1	0
B3	Baker Beach T1	7/17/2012	8	0	0	0	14	0	1	0
B3	Baker Beach T1	7/17/2012	5	0	0	1	7	0	0	0
R3	Rodeo Beach T1	7/18/2012	12	0	0	0	4	0	9	0
R3	Rodeo Beach T2	7/18/2012	10	1	0	0	0	0	5	0
R3	Rodeo Beach T3	7/18/2012	11	1	0	0	0	0	0	0
R3	Rodeo Beach T4	7/18/2012	1	0	0	1	1	1	3	0
LM2	Linda Mar T1	7/20/2012	12	0	0	0	7	0	0	1
LM2	Linda Mar T2	7/20/2012	7	0	0	0	1	0	1	68
LM2	Linda Mar T3	7/20/2012	10	0	2	0	7	0	0	1
LM2	Linda Mar T4	7/20/2012	12	0	0	0	6	0	0	2
S4	Stinson Beach T1	7/23/1012	55	3	0	0	21	1	1	0
S4	Stinson Beach T2	7/23/1012	81	0	0	0	10	0	22	0
S4	Stinson Beach T3	7/23/1012	42	0	0	6	58	0	8	0
S4	Stinson Beach T4	7/23/1012	91	0	0	4	46	0	20	4

Appendix 2

Trip ID	Location	Date	Plastic & Foam	Cloth	Glass & Ceramic	Metal	Paper & Cardboard	Rubber	Wood	Other
STK 1	St Kilda Beach	9/29/2013	265	1	6	37	5	1	1	0
STK 2	St Kilda Beach	10/2/2013	208	1	8	35	2	0	0	0
STK 3	St Kilda Beach	7/7/2013	474	0	0	6	1	5	3	0
STK 4	St Kilda Beach	10/23/2013	197	0	2	30	0	1	0	5
STK 5	St Kilda Beach	7/21/2013	392	0	6	1	0	0	1	1
STK 6	St Kilda Beach	12/14/2013	5163	70	170	495	20	20	1	1
STK 7	St Kilda Beach	9/1/2013	548	0	7	26	1	3	0	0
STK 8	St Kilda Beach	8/4/2013	360	0	6	50	12	0	1	0
STK 9	St Kilda Beach	10/6/2013	173	0	0	31	0	0	0	1
STK 10	St Kilda Beach	10/27/2013	379	1	0	35	0	0	0	2
LBQ 1	Lighthouse Beach Queenscliff	8/28/2012	195	1	84	19	9	2	21	2
TSB 1	Torquay Surf Beach	11/23/2013	908	3	77	129	87	12	23	54
CB1	Chelsea Beach	1/19/2014	699	3	2	28	7	14	6	1
WPB 1	Western Port Bay - Flinders Foreshore	9/7/2012	1671	5	32	83	80	34	64	38
C1	Cotters Beach	1/20/2014	229	1	1	0	0	6	6	1
FB1	Fairhaven Beach - Cathedral Rock	3/7/2012	603	8	57	53	9	14	14	0
FB2	Fairhaven Beach -	6/5/2012	1075	5	73	22	0	0	32	0

	Five Creeks									
FB3	Fairhaven Beach - Moggs	4/24/2012	233	7	5	7	14	0	54	0
FB4	Fairhaven Beach - Moggs	12/6/2012	417	3	20	46	0	2	9	0
FB5	Fairhaven Beach - Moggs	1/31/2013	406	9	54	0	58	0	10	0
FB6	Fairhaven Beach - Moggs	3/5/2014	183	28	51	21	38	6	14	4
FB7	Fairhaven Beach - Moggs	4/18/2013	88	0	29	13	93	319	6	4
FB8	Fairhaven Beach - Moggs	2/22/2012	318	0	12	6	0	5	64	4
FB9	Fairhaven Beach-Painkalac	3/7/2012	603	8	57	53	9	14	17	0
FB10	Fairhaven Beach-Painkalac	5/29/2013	1510	9	72	24	15	12	2	0
FB11	Fairhaven Beach-Painkalac	7/16/2013	429	3	49	68	6	402	37	0
FB12	Painkalac Estuary	8/20/2012	4654	63	22	6	1	34	9	0
FB13	Painkalac Estuary	1/30/2013	259	21	21	9	16	0	11	1
SB1	Squeaky Beach	2/14/2014	133	3	0	1	2	1	1	3